Construction of an Electronic Time-Delay and Pulse-Height Analyser with Associated Equipment. Application to Measurements on Short-lived Alpha-Emitters and Nuclear Isomers

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UPPSALA 1958

ALMQVIST & WIKSELLS BOKTRYCKERI AB

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INAUGURAL DISSERTATION

By

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FIL. LIC., SMÅL.

BY DUE PERMISSION OF THE FACULTY
OF SCIENCE OF THE UNIVERSITY OF UPPSALA
TO BE PUBLICLY DISCUSSED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY IN THE LECTURE HALL
OF THE INSTITUTE OF PHYSICS ON MAY 22, 1958
AT 10 A.M.

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The papers to be summarized below are as follows:

I. P. A. Tove: A flexible 20-channel time-delay and pulse-height analyser. Equipment for pulsed bombardment study of short-lived nuclei in a cyclotron. *Arkiv för Fysik 13*, 579 (1958).

Abstract: A multi-channel pulse analyser is described which is suitable for time-delay analysis of events in the range from 1 microsecond to minutes or more. Applications are lifetime measurements on isomers in this region and, with auxiliary equipment, pulsed bombardment studies of short-lived nuclei produced in an accelerator. The time sorting is done by count channels which are succesively opened and shut. The analyser is easily converted to a pulse-height analyser.

II. P. A. Tove: Alpha-emitters with short half-life induced by protons on heavy elements. *Arkiv för Fysik 13*, 549 (1958).

Abstract: Alpha-emitters with short half-life have been produced by pulsed bombardment in a synchro-cyclotron. The energies were measured with the help of the magnetic field of the cyclotron, and the decay times with an electronic time analyser. New data for α-emitters in the region between uranium and bismuth are given.

The results from bombardment of thorium are in accordance with previous information about the Th^{224} and Th^{223} series, and yield half-lives for Th^{224} and Th^{223} of respectively 1.05 ± 0.05 sec. and 0.9 ± 0.1 sec. Information about further alpha-peaks in the 1 sec. region is obtained and the possibility that these are due to the Pa^{224} and Pa^{225} decay series is discussed. The main result from irradiations of Ra is a check of previous data, yielding nuclei with half-lives in the range 0.5 to 40 sec. No alpha-emitters with lifetimes in the second region were obtained from uranium, lead, thallium, gold and platinum targets. Bombardments of bismuth yield four new alpha-emitters which from alpha-systematics are assigned to Po isotopes $Po^{195-192}$.

III. P. A. Tove: Electronic time analyser applied to the measurements of the half-lives of meta-stable nuclear states. *Nuclear Instruments, 1*, 95 (1957).

Abstract: An electronic 20-channel time analyser has been applied to the measurements of the half-lives of meta-stable nuclear states in the 100 μsec. region. The electronic circuits are described and measurements principles discussed, with special regard to the possibility of measuring longer-lived states.

IV. P. A. Tove: Automatic single-channel pulse-height analyser. *Nuclear Instruments, 2,* 1, 1958.

Abstract: An automatic single-channel pulse-height analyser is described. It works with a variable step attenuator to give 300 channel positions and has constant relative channel width.

V. E. Arbman and P. A. Tove: Isomeric state in Bi^{206}. *Arkiv för Fysik, 13,* 61 (1957).

Abstract: A half-life of 7.8 ± 0.3 μsec. has been measured for the 59.9 keV $E2$ transition in Bi^{206}. Delayed coincidence studies show that all strong gamma rays from the decay of Po^{206} precede the 59.9 keV transition. The spins of the levels in Bi^{206} are discussed.

VI. G. Andersson, P. A. Tove, B. Jung and I. B. Svensson: The isomeric transitions in Tl^{197} and Tl^{195}. *Nuclear Physics, 3,* 493 (1957).

Abstract: Internal conversion electrons from the isomeric transitions in Tl^{197} and Tl^{195} have been studied in high resolution β-spectrometers. The intensity ratios of the lines, when compared with recent theoretical values, were found to confirm the multipole assignment $E3$ for both transitions. The γ-energies were established as 222.45 ± 0.05 keV (Tl^{197m}) and 99.1 ± 0.1 keV (Tl^{195m}).

The half-lives of Tl^{197m} and Tl^{195m} have been measured as 0.55 ± 0.10 sec. and 3.5 ± 0.4 sec., respectively, using rapid chemical techniques and a multi-channel method of time analysis. Pulse-height spectra of the short-lived activities were found to support the mass assignments.

SUMMARY

Time sorting of pulses from radiation detectors has been an important aid in solving several problems in nuclear physics. Perhaps the most important application is the measurement of a radioactive decay by determining the change in time of the activity.

The present investigations have been concerned with decay measurements on short-lived nuclei by the help of an electronic analyser which collects and displays the time distribution of pulses obtained in a rapid decay, during a time ranging from microseconds to minutes. Such an instrument is called a time-delay analyser, or time analyser for short. The present instrument is described in paper I which also discusses arrangements for repetitive short irradiations in a cyclotron when used for the study of short-lived nuclei produced in a nuclear reaction.

The circuits can also be arranged to function as a multichannel pulse-height analyser. This works on the principle of converting the measurement of pulse height to a time measurement.

The pulsed bombardment method makes it possible to extend our knowledge about unstable nuclei, for which ordinary methods used in nuclear spectro-

scopy are not possible. One domain is the investigation of alpha-emitters described in paper II. A simultaneous measurement of alpha-energy and decay time is possible through the use of the cyclotron as a magnetic spectrometer.

The application of the analyser for measurements on isomers in a difficult region of lifetimes between about 10 μsec. and 0.1 sec. is discussed in paper III. Isomers within this region are too short-lived for ordinary decay measurements and the common single-channel delayed coincidence method is difficult and slow to apply because of the weak sources needed for acceptable ratio of true to chance coincidences. In overcoming this a valuable feature of the analyser is its being a multichannel instrument, i.e. a device that accepts and measures every event irrespective of its specific delay. In these experiments scintillation detectors have been used. The more or less complete selection, from a complex spectra, of the timing pulses due to the feeding and de-exciting transitions of the isomeric state is made possible by pulse-height selecting devices. A single-channel discriminator used for this purpose, and in automatic records of the spectra, for identification purposes, is described in paper IV. The instrument combines the convenience of the rate-meter type of "sliding" discriminator with the accuracy of a pulse-counting device, and has constant relative channel width.

Paper V is a description of a measurement of an isomer with a lifetime in the lower end of the suitable range of the method. Other examples are the determination of the half-life of the 516 keV $E3$ transition in Pb^{206} to 123 ± 4 μsec. and that of the 460 keV $E3$ transition in Tl^{202} to 475 ± 30 μsec.

Paper VI describes direct decay measurements on longer-lived isomers in the second region. The isolation of these isomers is made possible by fast "milking" techniques, from long-lived parents. The analyser arrangement is essentially the same as that used in the cyclotron experiments.

ACKNOWLEDGEMENTS

The author wants to express his sincere thanks to Professor The Svedberg for his generous support and encouragement during the various stages of this study.

The stimulating contact and discussions with Professors Kai Siegbahn and Per Ohlin at the Physical Institute have been of vital importance for the progress of the work.

To collaborators and to all members of the Gustaf Werner Institute who have contributed to this work, I am thankfully indebted.

The present investigation was financially supported by the Swedish Atomic Energy Commission, which is gratefully acknowledged.

Uppsala, April 1958 *Per-Arne Tove*